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INTERNATIONAL APPLICATION PUBLISHED UNDER THE PATENT COOPERATION TREATY (PCT)

(51) International Patent Classification 6 : B03C 3/68	A1	(11) International Publication Number: WO 98/42444 (43) International Publication Date: 1 October 1998 (01.10.98)

(21) International Application Number: PCT/SE98/00467

(22) International Filing Date: 16 March 1998 (16.03.98)

(30) Priority Data:
9701139-9 26 March 1997 (26.03.97) SE

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(81) Designated States: AL, AM, AT, AT (Utility model), AU, AZ, BA, BB, BG, BR, BY, CA, CH, CN, CU, CZ, CZ (Utility model), DE, DE (Utility model), DK, DK (Utility model), EE, EE (Utility model), ES, FI, FI (Utility model), GB, GE, GH, GM, GW, HU, ID, IL, IS, JP, KE, KG, KP, KR, KZ, LC, LK, LR, LS, LT, LU, LV, MD, MG, MK, MN, MW, MX, NO, NZ, PL, PT, RO, RU, SD, SE, SG, SI, SK, SK (Utility model), SL, TJ, TM, TR, TT, UA, UG, US, UZ, VN, YU, ZW, ARIPO patent (GH, GM, KE, LS, MW, SD, SZ, UG, ZW), Eurasian patent (AM, AZ, BY, KG, KZ, MD, RU, TJ, TM), European patent (AT, BE, CH, DE, DK, ES, FI, FR, GB, GR, IE, IT, LU, MC, NL, PT, SE), OAPI patent (BF, BJ, CF, CG, CI, CM, GA, GN, ML, MR, NE, SN, TD, TG).

Published
With international search report.
Before the expiration of the time limit for amending the claims and to be republished in the event of the receipt of amendments.

(54) Title: METHOD TO CONTROL CURRENT SUPPLY TO AN ELECTROSTATIC PRECIPITATOR

(57) Abstract

In an electrostatic precipitator unit, comprising discharge electrodes and collecting electrodes between which a varying high voltage is maintained, a pulsating direct current supplied thereto is controlled. The frequency, the pulse height and/or the pulse length of the pulsating direct current are varied, so as to obtain a plurality of frequency–height–length–combinations. The charges of the individual pulses are being measured or calculated. The frequency–height–length–combinations resulting in flashover between the discharge electrodes and the collecting electrodes are registered. The size of the pulse charge at flashover is used for selection of the frequency–height–length–combination of the pulsating direct current.

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METHOD TO CONTROL CURRENT SUPPLY TO AN ELECTROSTATIC PRECIPITATOR

FIELD OF THE INVENTION

The present invention relates to a method for use in an electrostatic precipitator unit, comprising discharge electrodes and collecting electrodes between which a varying high voltage is maintained, to control a pulsating direct current supplied thereto.

The method is especially well suited when the pulsating direct current is generated by a pulse means, such that the length, height and frequency of the pulses can be varied independently of each other. The method can however be used even if, for instance, the pulse height is constant for all pulse lengths and frequencies, such as in a pulse-width-modulated high-frequency converter. The method can also be used when the pulsating current has the form of a pulse train which is synchronised with the frequency of the mains voltage and in which the pulses are generated by supplying a part of a half wave of the mains voltage by means of a phase-angle-controlled rectifier (thyristor), after step-up transformation to the electrodes of the precipitator, whereupon a plurality of periods of the mains voltage are allowed to pass without any current being supplied to the electrodes.

BACKGROUND OF THE INVENTION

Electrostatic precipitators are often the most preferred dust separator option, especially for flue gas cleaning. They have a robust design and are highly reliable in operation. Moreover, they are very efficient, degrees of separation above 99.9% are not unusual. Since, when compared with textile barrier filters, their operating costs are low and the risk of breakdown and stoppage owing to malfunction

is considerably smaller, they are a natural choice in many contexts.

The requirements of the authorities on the emission level, for example, from plants where fossil fuels are being burnt, are directed to the total amount of emission. This means that disturbances in the operation of an electrostatic precipitator have to be considered. The most common disturbance when using electrostatic precipitators is the rapping of the filter, which has to be performed in order to be able to remove the dust collected on the collecting electrodes from the filter. During this rapping the emissions are increased temporarily very strongly if no special measures are taken.

A problem that is often difficult to master appears when dust with high resistivity is to be separated. In such operating cases one is often forced to operate with extremely unfavourable operating parameters due to the risk for partial discharges in the gradually growing dust layer on the collecting electrodes. When partial discharges occur in the dust layer the effect will i.a. be emission of charges and dust from the collecting electrodes, so-called back corona.

In order to optimise the operation and reduce the energy consumption at the same time as the separation is improved, several methods for pulse feeding of the current to the filter have been suggested. Examples are found in US-4,052,177 and US-4,410,849. The former method suggests feeding of pulses in the order of microseconds, which means that the rectifiers become very expensive. The latter method suggests pulses in the order of milliseconds, which may rather simply be achieved by selectively controlling quite common thyristor rectifiers, to which mains frequency alternating current are supplied.

The continued technical development in the field of power-electronics has also made it possible, via a frequency conversion to an intermediate frequency of 10 to 50 kHz, to essentially reduce the size of the transformers and

rectifiers. By pulse-width modulation of the frequency, pulse lengths down to 0.02-0.10 ms and a quick adjustment with reliable control of the current supply to the electrostatic precipitator are obtained by relatively simple means. Such methods are described in i.a. DE 35 22 568 and WO 88/07413.

With the new techniques, the number of control parameters have increased and, hence, the complexity of the control systems. Unfortunately, this also means that the adjustment itself increases the disturbance in the function of the separator. In the same way as the emissions increase when the filter is being rapped, the emissions will increase during the time the adjustment proceeds or set control parameters are being checked.

If the adjustment is performed manually by means of the reading of an opacimeter (tester for the optical density of smoke), such a long time is required for the adjustment that, under varying operation conditions, very considerable emissions may very well be produced during the adjustment proper, which make up a substantial part of the total emissions, in addition to the emissions due to the rapping. Furthermore, there is a risk that operational variations affect the adjustment so that the optimisation will fail if considerable changes in dust concentration or gas temperature occur during the time needed for the adjustment.

Further, as already mentioned, the rapping of the collecting electrodes results in a temporarily strongly increased dust concentration of the outgoing gas. Each measurement of the opacity for the adjustment of the current supply should therefore only occur during periods when no rapping is being performed. As this occurs very often in the precipitator situated closest to the furnace, or any other dust source, there is a great risk that the rapping still affects the adjustment in a decisively negative way.

Therefore, it is highly desirable to provide a method for quick and reliable adjustment of the current supply to the electrostatic precipitator based only on electrical

measurements in the precipitator involved or associated rectifier. It has been shown that even if the rapping very strongly influences the dust concentration of the outgoing gas from the precipitator, the current-to-voltage ratio in a precipitator is only marginally changed thereby.

Some tests with optimisation based only on measurement of electrical quantities have been performed, and as examples thereof reference is made to US-4,311,491, EP-465 547 and EP-184 922. These examples have, however, remaining shortcomings when it comes to adaptability to process changes, and reliability when it comes to finding the setting which gives minimum energy consumption during varying relations when separating highly resistive dust. An advanced and in many cases a correct method is further described in WO 93/10902. However, this method is afflicted with the shortcoming that it is complicated to implement in a control unit, and it becomes more and more difficult to use the shorter the pulses are.

THE OBJECT OF THE INVENTION

The methods hitherto tested, when separating highly resistive dust, have been found not always to yield the optimum parameter combination. This is the fact particularly for the methods based on measurement of the dust concentration, but it also applies to hitherto proposed methods that are based on measurement of electrical quantities.

In general it is further the fact that all adjustment activities means that the normal operation is disturbed. The operation parameters must be changed somewhat from the setting, which has been considered as the best one, in order to determine if the parameter combination still is the best one. The disturbance continues often during a considerable time interval.

It is a main object of the present invention to provide an improved method for selection of operating parameters for electrostatic precipitators when separating "difficult" dust, for instance dust having high resistivity.

Another object of the present invention is to provide a method, based on measurement of electrical quantities only, which quite general gives a quicker and safer adjustment of electrostatic precipitators.

It is especially an object of the present invention to provide a method, which can be used for every pulse feeding all the way down to pulse lengths of the order of 1 microsecond and therebelow, and which without complicated calculation programs with great safety gives the best operating point for the electrostatic precipitator.

SUMMARY OF THE INVENTION

The present invention relates to a method for use in an electrostatic precipitator unit, comprising discharge electrodes and collecting electrodes between which a varying high voltage is maintained, to control a pulsating direct current supplied thereto. In the method according to the invention the frequency, the pulse height and/or the pulse length of the pulsating direct current are varied, so as to obtain a plurality of frequency-height-length combinations.

For each of the combinations the charges of the individual pulses are measured or calculated. The frequency-height-length-combinations resulting in flashover between discharge electrodes and collecting electrodes are registered. The size of the pulse charge at flashover is used for selection of the frequency-height-length-combination of the pulsating direct current.

GENERAL DESCRIPTION OF THE INVENTION

One of the fundamental observations in the operation of electrostatic precipitators is that the separation becomes more efficient when the voltage between discharge electrodes and collecting electrodes is increased. It is essentially found that the physical migration velocity of the particles depends on the square of the electric field strength and, thus, also on the square of the voltage.

Efficient separation therefore requires a high voltage, the higher the better. The usable voltage interval is limited upwards by the fact that flashover occurs between the electrodes. In problem-free operation, one therefore tries to operate as close to the flashover limit as possible.

High voltage essentially also means that the current density becomes high. If the dust that is separated conducts current well, this involves no problem, but if the dust has high resistivity and the current density in the gas is high, the separated dust layer on the collecting electrodes will be charged such that the electric field strength in the layer will be sufficient to conduct the same high current density through the dust layer. This often results in electric breakdown of the dust layer, so-called back corona, if the current density is not limited.

It has been known for over 50 years that pulse feeding of current to electrostatic precipitators improves the performance of the precipitator when the dust is difficult to separate, i.e. is highly resistive. As mentioned above, this has resulted in attempts, sometimes with highly complex equipment, to supply the necessary energy to the precipitator, by also using very short pulses.

Gradually, it was found that excellent results were obtained also with pulses of the same order as the half waves of the regular alternating voltage used in the distribution networks. This was explained by the fact that charge variations in the dust layer, which in charge growth

cause the so-called back corona, have a time constant of about 1 s. This should, however, not be interpreted to mean that it takes 1 s to charge the layer, although this mistake is frequently made, but that it takes about one second for the layer to be discharged when the charging has ceased. The charging is controlled merely by the supplied charge, i.e. the size of the current. Thus, the charging can be effected in less than one millisecond if the current intensity is sufficient.

Pulse feeding of the current also affects the flashover voltage to some extent, and the current at flashover to a very great extent. Moreover, the charge in each individual pulse is, at flashover, essentially a function of the pulse frequency. It is of course possible to generate flashover with optionally large pulses. In this case and below, charge at flashover often means the minimum charge, which at the frequency involved, or on other given conditions, results in flashover.

If the pulses are presupposed to be extremely short and are supplied at such intervals that the dust layer has time to lose the major part of its charge between the pulses, the charge that must be supplied to an individual pulse to cause flashover will be essentially constant, independently of the pulse frequency. If the pulse frequency is increased, a greater and greater part of the charge from the preceding pulse will successively remain in the precipitator when the next pulse comes, and thus the charge supply that is necessary for flashover decreases. If the pulses come close behind each other, each individual pulse can be very small at flashover.

If we assume that the resistivity of the dust layer is so low that there is no risk of back corona, the limit value of the size of the pulse at high frequencies is zero. On the other hand, it may be said that the necessary pulse charge at flashover grows with the interval between the pulses, from zero when the interval is very short to a constant value when the interval is long, usually seconds. Fig. 1 illustrates this principle. By interval between the pulses

is here and below meant T=1/f, where f is the pulse frequency.

If the form of the pulses changes, it will be found that a longer pulse will mean that a greater charge is necessary for flashover than in case of a shorter pulse if the pulse frequency is kept constant. This depends on the filter losing part of the charge even during the pulse, i.e. the effective charge may be considered to have decreased. A group of curves according to Fig. 2 is obtained. The relationship between the curves of course depends to a great extent on the resistivity in the dust layer, if there is one.

A highly resistive layer of dust will change the appearance of the curves. It will be found that it is sometimes possible to supply a very high current without even approaching the expected flashover voltage. Nevertheless, flashover sometimes occurs at a very low voltage, and sometimes the maximum current of available rectifiers can be supplied without any flashover occurring.

In the cases where one tries to obtain a flashover pulse charge by pulse feeding when there is a highly resistive layer of dust on the collecting electrode, it will be found that at low frequencies about the same result will be obtained as in the case where the dust is of low resistivity, whereas at high frequencies a growing pulse charge is required, instead of a decreasing. The fundamental connection between pulse charge at flashover and frequency for very short pulses is evident from Fig. 3.

If a new curve is registered for a different pulse form, it will be found that, like in the case of low-resistive dust, it will be higher when the pulse is longer. Moreover, it will be found that certain pulse lengths do not result in flashover above a certain frequency. One may generally find a tendency towards a minimum for a certain frequency. This can be more or less pronounced and depends on the resistivity of the dust involved. A group of curves is shown in Fig. 4.

This minimum can be said to depend on the fact that the limitation of the electrostatic precipitator at short intervals between the pulses is set by the dust layer, while at long intervals between the pulses, it is determined by what happens in the gas flowing through the precipitator. The present invention is based on the unpredictable disclosure that there exists a relationship between the efficiency of the precipitator and the smallest pulse charge that is required for flashover. One should choose to operate in the area where one is close to the smallest pulse charge for flashover with the given limitations of pulse means and other equipment.

According to the present invention, it is therefore suggested that the length, height and frequency of the pulses are varied such that, for instance, for each frequency the smallest charge which results in flashover is determined, and then this procedure is repeated for other frequencies and these values of the pulse charge at flashover are used to select parameters for the continued operation. An examination of a sufficiently great frequency range is suitably carried out so as to find a certain frequency which gives the very lowest value of the pulse charge at flashover, above which frequency an increased pulse charge is again obtained, and then the operation is continued at a frequency close to this value. Concurrently with variations in the gas that is to be cleaned, the size of the pulse at this frequency is then varied so as to be close to the flashover limit. Preferably, precisely the frequency that gave a minimum for the charge is selected.

The preferred variation of the appearance of the pulses is such that the maximum height of the pulse is selected, and the width of the pulse is varied for a varying charge to be obtained. One alternative is to keep the relationship between length and height essentially constant. Of course, it is within the scope of the invention to keep the frequency constant and vary the pulse length and pulse height. The choice of control algorithm depends on the

construction of the pulse means. A constant height is preferable when using pulse-width-modulated high-frequency converters. When using mains frequency and thyristors, it is necessary to accept that width and height co-vary in a manner determined by the supply voltage and that the pulse frequency can only be varied as submultiples of the supply frequency. When using high-frequency converters, the pulse frequency may be varied, for instance, between 1 Hz and 10 kHz, preferably between 1 Hz and 1 kHz.

One of the great advantages of the invention is its simplicity in respect of measuring technique. The fact that it is easy to keep a check on the frequency in the control means makes it possible to calculate the charge of the pulses on the basis of the size of the current by dividing the current by the number of pulses per unit of time. When using pulse-width-modulated high-frequency converters, the pulse charge can be calculated on the basis of the pulse width.

BRIEF DESCRIPTION OF THE DRAWINGS

The invention will now be described in more detail with reference to the accompanying drawings in which

Fig. 1 shows the basic relationship between the pulse charge at flashover and the interval T between the pulses when separating dust with low resistivity;

Fig. 2 shows the corresponding relationship for varying pulse lengths;

Fig. 3 shows the basic relationship between the pulse charge at flashover and the interval T between the pulses when separating dust with high resistivity;

Fig. 4 shows the corresponding relationship for varying pulse lengths;

Fig. 5 shows a simplified wiring diagram for a device suitable for carrying out the proposed method.

DESCRIPTION OF A PROPOSED EMBODIMENT

Fig. 5 is a fundamental wiring diagram of a voltage-converting device which supplies high-voltage direct current to a precipitator 1. The device comprises a three-phase rectifier bridge 2, a pulse generator 3, a transformer 4, a one-phase full-wave rectifier bridge 5, a choke 6, and control equipment 7 with precision resistors 8, 9 and 10.

The three-phase rectifier bridge 2 comprises six diodes 21-26 and is, via three conductors 27, 28, 29 connected to ordinary three-phase AC mains.

The pulse generator 3 comprises four transistor 31-34 and four diodes 35-38. The transistors are controlled by their bases being connected to the control equipment 7.

The full-wave rectifier bridge 5 consists of four diodes 51-54.

The control equipment 7 is connected not only to the transistor 31-34, but also to a precision resistor in series with the precipitator 1, for measuring the current to the electrodes of the precipitator, and to a voltage divider comprising two resistors 9 and 10 connected between the electrodes of the precipitator for measuring the voltage between them.

The device functions as follows. Via the conductors 27-29, the rectifier bridge 2 is supplied with three-phase alternating current. This is rectified and is transferred, via conductors 11 and 12, as a direct current to the pulse generator 3. The control equipment 7 controls the conducting periods of the transistors 31-34 such that a pulse-width-modulated voltage, essentially formed as a square wave, is

supplied, via conductors 13 and 14, to the primary side of the transformer 4.

The voltage induced in the secondary winding of the transformer 4 is rectified by the rectifier bridge 5 and, via the smoothing choke 6, the obtained direct current is supplied to the electrodes of the precipitator 1.

As mentioned above, the control equipment 7 controls the transistors 31-34 and moreover monitors the current and voltage of the precipitator via the resistors 8 and 10. Since the conducting periods of the transistors are controlled, the pulse width of the generated, essentially square-wave-formed current can be varied and, consequently, both current and voltage in the precipitator are controlled.

In an exemplifying application of the invention, the above described device is thought to operate with an intermediate frequency of 50 kHz and a pulse frequency of 10 Hz. The pulse height is the maximum one for the means and the current is controlled so that the flashover limit is continuously sensed by varying the pulse length somewhat around an average value of about 1 ms.

During the adjustment the pulse frequency is decreased to 5 Hz and the pulse length is increased step-by-step until flashover occurs. The pulse charge is registered. At successively increased pulse frequency, up to values above 10 Hz, the procedure is repeated so that for each frequency the smallest flashover charge is determined. The frequency for which the smallest pulse charge during the adjustment is registered, is used in the continued operation. At this frequency the pulse length is then varied in an usual manner so that essentially maximum current can be supplied. The interval between the adjustments is to be determined based on experience, but as the adjustment does not mean a total stoppage or a decisive disturbance it can without inconvenience be performed with short intervals if the operating parameters are varied.

CLAIMS

1. A method for use in an electrostatic precipitator unit, comprising discharge electrodes and collecting electrodes between which a varying high voltage is maintained, to control a pulsating direct current supplied thereto, whereby the charges of the individual pulses are measured or calculated, c h a r a c t e r i s e d by the steps of

varying the frequency, the pulse height and/or the pulse length of the pulsating direct current, so as to obtain a plurality of frequency-height-length combinations;

registering the frequency-height-length combinations resulting in flashover between discharge electrodes and collecting electrodes, and

using the size of the pulse charge at flashover for selecting the frequency-height-length combination of the pulsating direct current.

2. Method as claimed in claim 1, whereby the pulses are generated by a pulse means, c h a r a c t e r i s e d i n

that the height of the pulses is selected as the one which the pulse means can generate maximally, and that the adjustment occurs by varying the pulse length and frequency.

3. Method as claimed in claim 1, c h a r a c t e r i s e d i n

that the relation between the height of the pulses and the length is kept constant during the adjustment.

4. Method as claimed in claim 1, c h a r a c t e r i s e d i n

that the pulse frequency is kept constant, and that the adjustment occurs by varying the pulse length and frequency.

5. Method as claimed in claim 1, whereby the pulse is generated by that phase-angle-controlled rectifiers transmit at least a part of a half wave from an essentially sinus-shaped mains voltage, which after step-up transformation and rectification is supplied to the electrostatic precipitator, c h a r a c t e r i s e d i n

that the frequency is varied by that the phase-angle-controlled rectifiers are kept conducting during a part of a half wave or a full half wave and thereafter is kept essentially non-conducting during one or more half waves.

6. Method as claimed in any one of the claims 1 to 4, whereby the pulses are generated by a pulse means, in the form of a high-frequency converter, by pulse-width modulation of an intermediate frequency, and the intermediate frequency of the pulse means is between 1 and 100 kHz, preferably between 10 and 50 kHz, c h a r a c t e r i s e d i n

that the pulse frequency is varied between 1 Hz and 10 kHz, preferably between 1 Hz and 1 kHz.

7. Method as claimed in any one of the preceding claims, c h a r a c t e r i s e d i n

that the frequency-height-length combination for which the required pulse charge at flashover is the smallest one is determined, and

that a pulse frequency close to the one obtain at said frequency-height-length combination is selected for the continued operation.

8. Method as claimed in any one of the claims 1, 2, 3, 5 or 6, characterised in

that during the adjustment one begins with a frequency which is lower than the one involved for the operation precisely before the adjustment, and

that at successively increasing frequency one determines, for the frequency involved, the smallest required pulse charge at flashover until one has passed a minimum for the pulse charge at flashover, and thereafter selects pulse parameters close to those which gave the minimum for the continued operation.

9. Method as claimed in any one of the preceding claims characterised in

that the current to the electrostatic precipitator is measured, and

that the charge of the individual pulse is calculated as the average value of the current divided by the pulse frequency.

10. Method as claimed in any one of the claims 2, 6, 7 or 8, characterised in

that the charge of the individual pulse is calculated by the aid of the pulse width.

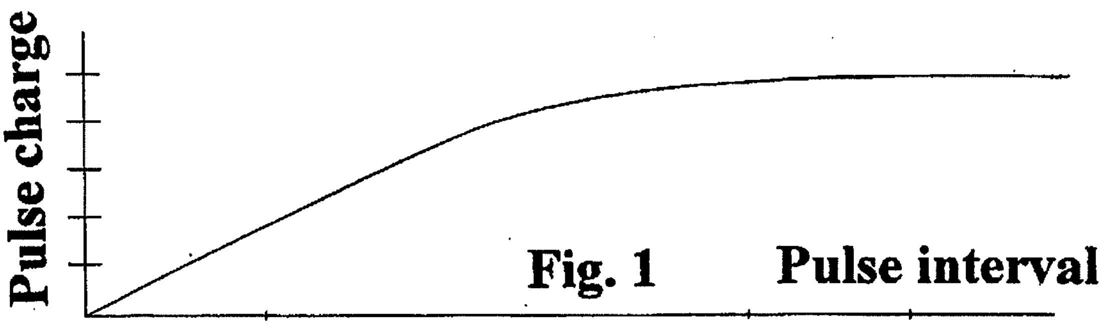

Fig. 1

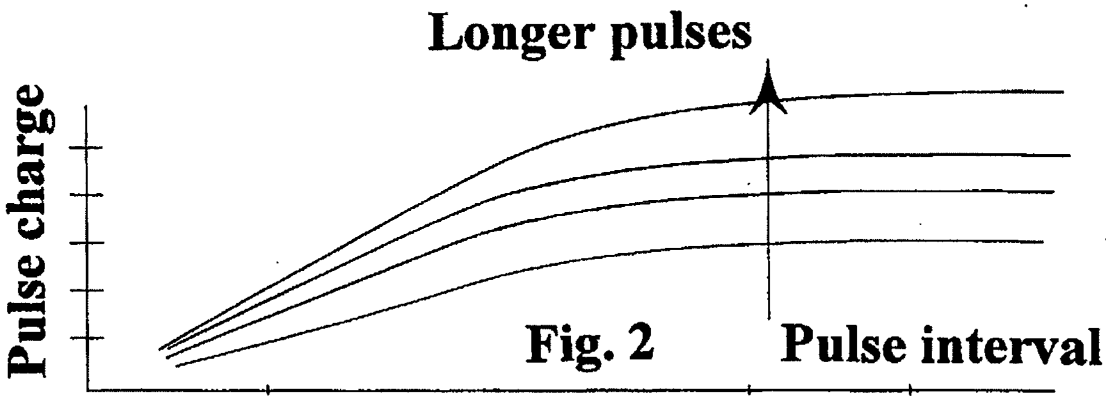

Fig. 2

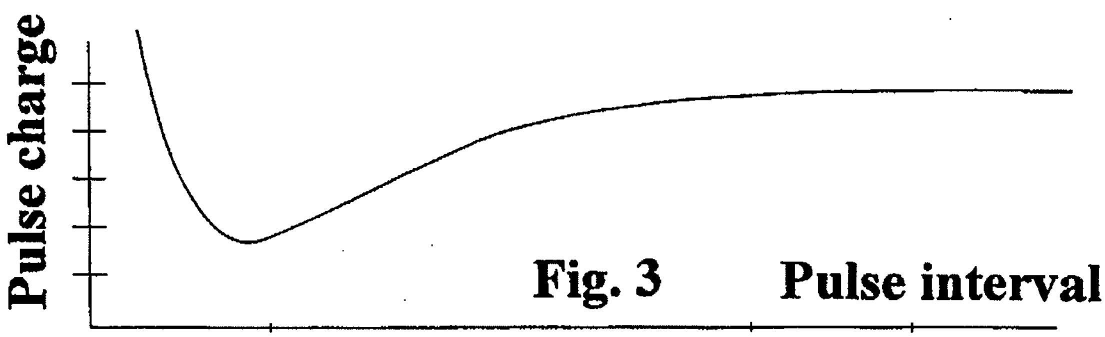

Fig. 3

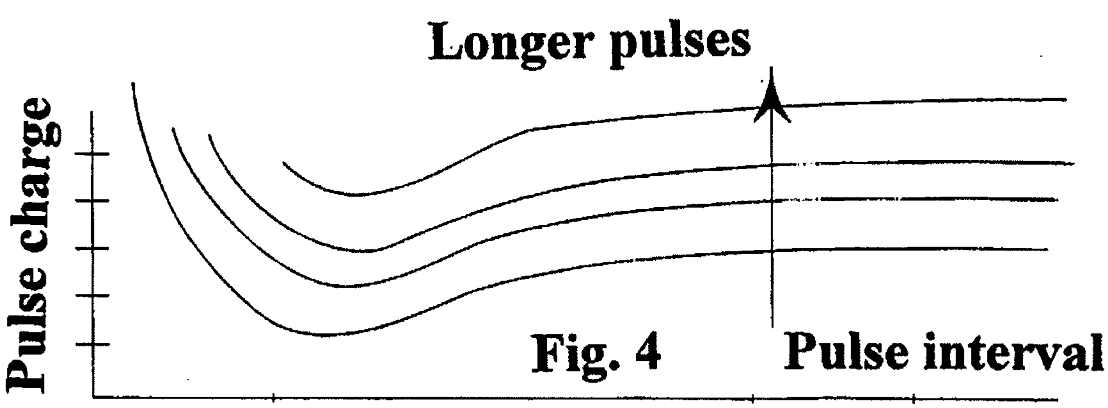

Fig. 4

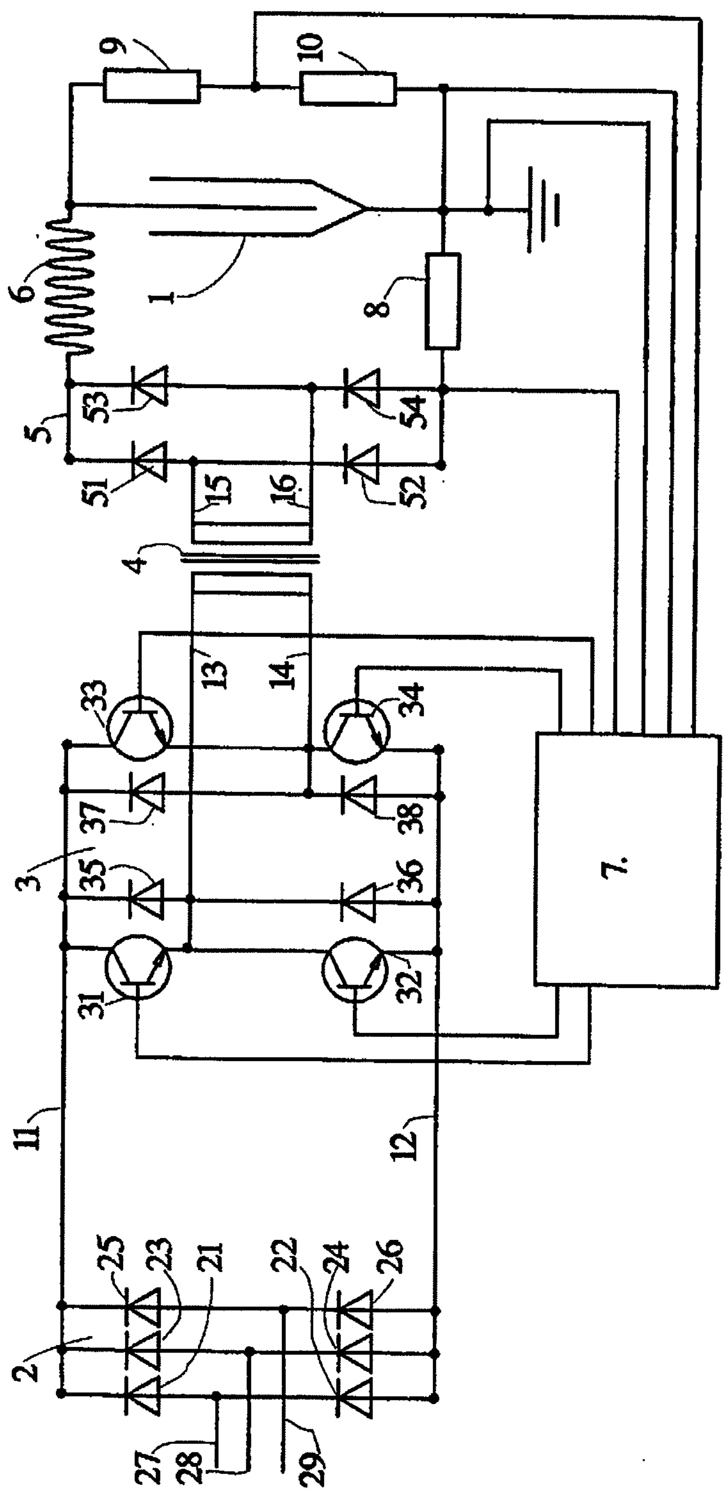
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Fig. 5

INTERNATIONAL SEARCH REPORT

International application No.
PCT/SE 98/00467

A. CLASSIFICATION OF SUBJECT MATTER

IPC6: B03C 3/68

According to International Patent Classification (IPC) or to both national classification and IPC

B. FIELDS SEARCHED

Minimum documentation searched (classification system followed by classification symbols)

IPC6: B03C

Documentation searched other than minimum documentation to the extent that such documents are included in the fields searched

SE,DK,FI,NO classes as above

Electronic data base consulted during the international search (name of data base and, where practicable, search terms used)

WPI

C. DOCUMENTS CONSIDERED TO BE RELEVANT

Category*	Citation of document, with indication, where appropriate, of the relevant passages	Relevant to claim No.
A	WO 9310902 A1 (ABB FLÄKT AB), 10 June 1993 (10.06.93), abstract --	1-10
A	WO 9420218 A1 (ABB FLÄKT AB), 15 Sept 1994 (15.09.94), abstract --	1-10
A	EP 0184922 A2 (F.L. SMIDTH & CO.), 18 June 1986 (18.06.86), abstract --	1-10
A	WO 9416820 A1 (ABB FLÄKT AB), 4 August 1994 (04.08.94), abstract -- --------	1-10

☐ Further documents are listed in the continuation of Box C. ☒ See patent family annex.

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INTERNATIONAL SEARCH REPORT
Information on patent family members

30/06/98

International application No.
PCT/SE 98/00467

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